IN THE UNITED STATES PATENT AND TRADE MARK OFFICE

In re US Application of Bartlett, Ross John et al.

Serial No.: **10/561,185**

Filed: **March 1, 2007**

Examiner: **AHMAD, CHARISSA L**

Art Unit: **3635**

DECLARATION UNDER RULE 132

I, Ross Ian Dempsey of 11 Palatine Street, Calamvale, Queensland, Australia, do solemnly and sincerely declare as follows:

I am a coinventor of and am familiar with the referenced US patent application in the name of Bartlett et al. and am familiar with the Office Action dated July 10, 2008 issued therein and with the prior art references cited in the Office Action.

I obtained the degree of Bachelor of Engineering (Civil) at Queensland Institute of Technology (now Queensland University of Technology) in 1977 and the degree of Master of Engineering (Research) at the Queensland University of Technology in 1993. The title of my Master of Engineering thesis was "Development of Structural Connections for Hollow Flange Beams". After graduating with the Bachelor Degree in Engineering I was employed between 1977 and 1988 by Evans Deakin Industries Limited, a large engineering company engaged in design, fabrication and construction of steel structures and associated mechanical, process and electrical equipment for power station, mining and industrial facilities. During my employment with Evans Deakin Industries I progressed to the position of Senior Design Engineer in the design office, and also held positions of site engineer and site manager for several construction projects.

From 1988 to 1995 I was employed by Tube Technology Pty Ltd, a subsidiary of Palmer Tube Mills (Aust) Pty Ltd, at the time one of Australia's largest manufacturers of ERW pipe and tube, and the only manufacturer of DERW Hollow Flange Beams. Whilst employed with Tube Technology Pty Ltd I was responsible for the engineering development of the Hollow Flange Beam, and gained extensive knowledge and experience in its design and manufacture, as well as the design of structures incorporating those beams. From 1995 to 1998 I worked for myself producing product design manuals for Tubemakers of Australia and BHP Steel. From 1998 to 2000 I worked for Multispan Australia as the design engineer for steel framed low-rise buildings. From 2000 to 2001 I worked for Smorgon Steel Tube Mills (formerly Palmer Tube Mills) during the initial stages of the development of the LiteSteel™ beam, the registered name of the hollow flange channels manufactured by Smorgon Steel Tube Mills. The LiteSteel™ beam is defined by the claims of the present patent application. From 2001 to 2003 I worked for Big Country Buildings as the design engineer for steel framed low-rise buildings. From 2003 to 2005 I worked for Warren Brown and Associates Consulting Engineers designing steel framed housing and other

steel structures. During this time I wrote the engineering design manuals for the LiteSteel™ Beam.

In 2005 I joined Smorgon Steel Tube Mills (formerly Palmer Tube Mills) to continue research and development of the LiteSteel™ Beam following its release to the market. Smorgon Steel Tube Mills is now Onesteel Australian Tube Mills following the merger of Smorgon Steel with Onesteel. I am currently employed by Onesteel Australian Tube Mills. Another subsidiary of Onesteel, Smorgon Steel LiteSteel™ Products Pty Ltd, is the assignee of all right, title and interest in the present patent application.

I submit the present declaration as evidence of non-obviousness over the cited art of record, and in particular as evidence of unexpected results, concerning the claims of the present patent application.

In the Office Action dated July 10, 2008, the Examiner stated the following:

With respect to the dimensions, it would have been obvious to one of ordinary skill in the art at the time of the invention to provide the beam of Oliver et al. having the width, thickness and depth dimensions disclosed in Claims 1-9, since the dimensions would have been a matter of design choice and the beam of Oliver et al. would operate equally well with any desired dimensions. No unexpected results are obtained from the claimed dimensional ratios and as such they are viewed as nothing other than obvious choice of design.

I respectfully disagree with the Examiner. In my opinion, significant unexpected results compared to the prior art have been achieved by beams of the present invention that include the claimed dimensional ratios. Evidence of such significant unexpected results is set out below.

I will firstly address the geometrical proportions of the channel-shaped structural beam having hollow parallel sided flanges as defined in claim 1 of the present patent application.

Background

Hollow flange sections are very rare in practice, and the structural behaviour of them was not widely known, even amongst structural engineers, at the time of filing of the present application.

The term "hollow flange" used here assumes that the hollow flanges are fully enclosed both geometrically and structurally. That is, there are no unconnected portions around the perimeter of the flanges.

The buckling behaviour of hollow flange sections is illustrated in the graphs in Figure 1 which are extracted from Hancock (2007). Figure 2(a) shows the large increase in the buckling stress when the hollow flanges of a hollow flange beam are fully enclosed. Figure 1(a) and (b) both show the effect of lateral distortional buckling on hollow flange sections in reducing the buckling stress relative to the traditional Timoshenko flexural-torsional buckling formula.

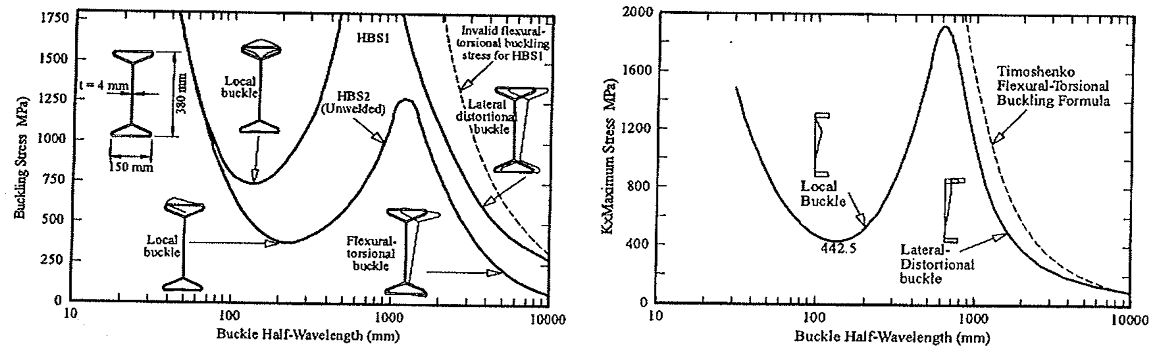


Fig. 3.15 Hollow Flange Beam - Buckling Stress versus Half-wavelength for Major Axis Bending

Fig. 3.16 LiteSteel Beam - Buckling Stress versus Half-Wavelength for Major Axis Bending

(a) **(b)**

Fig. 1 Extracts from Hancock (2007)

The hollow flange channels of the present invention are primarily used as structural beams in bending (flexure) about the major principal x axis (refer to Figure 2).

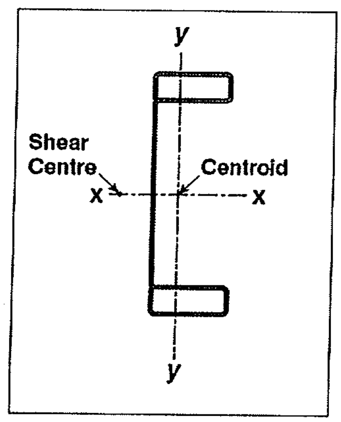


Fig. 2 Principal Axes of a hollow Flange Channel

Extensive analytical and experimental investigations have been undertaken by the inventors to determine the structural behaviour and capacity of hollow flange channels. From previous experience with the hollow flange beam defined in US patent 5,373,679 (known as a "Dogbone" beam), it was known that these sections are subject to what has become known as lateral distortional buckling (LDB). This buckling mode is not recognised in any structural design standards throughout the world, except in Australia. It was first introduced in AS/NZS 4600: 1996 Cold-Formed Steel Structures Standard following the introduction of the "Dogbone" into the market, but it was meant to cover generic hollow flange sections.

Later, this formula was modified in the new AS/NZS 4600: 2005 based on more extensive and detailed research undertaken by Mahendran and Mahaarachchi (2005 a, b, c, d and 2006) at the Queensland University of Technology (QUT). This research used hollow flange channels, and involved full scale testing and extensive finite element analysis. The

resulting equations to determine the bending capacity of sections subject to lateral distortional buckling, as given in AS/NZS 4600:2005, are given below, and these are plotted in Figure 3 for a typical hollow flange channel.

For $\lambda_d \leq 0.59$: $M_c = M_y$ Eq. 3.3.3.3(5)

For $0.59 < \lambda_d \leq 1.70$: $M_c = M_y\left(\frac{0.59}{\lambda_d}\right)$ Eq. 3.3.3.3(6)

For $\lambda_d > 1.70$: $M_c = M_y\left(\frac{1}{\lambda_d^2}\right)$ Eq. 3.3.3.3(7)

The first equation (3.3.3.3(5)) from AS/NZS 4600: 2005 represents yielding or local buckling of the section. The second equation (3.3.3.3(6)) represents lateral distortional buckling, and equation 3.3.3.3(7)) represents lateral torsional buckling. It can be seen that the lateral distortional buckling affects the medium unrestrained beam lengths. These equations are represented graphically in Figure 3.

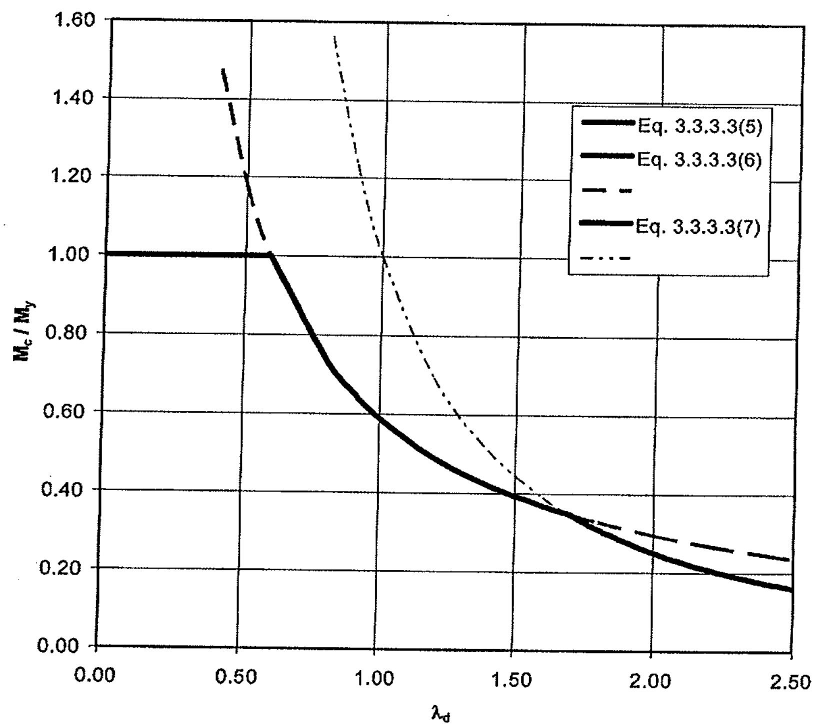


Fig. 3 Graphical Representation of AS/NZS 4600: 2005 Clause 3.3.3.3(b)

The plateau of the bending curve represents a beam which is fully laterally restrained, which means that the lateral restraints to the critical flange are very closely spaced and there is no global buckling of the beam. This is referred to as the section moment capacity

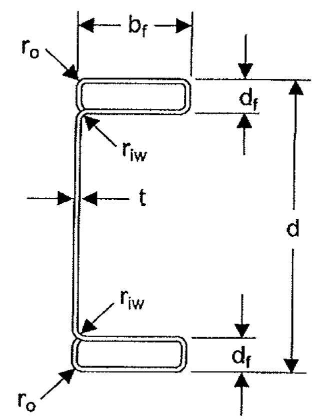
of the section. The curve represents a reduction in the bending capacity due to global buckling, either lateral distortional or lateral torsional buckling when the lateral restraints are spaced further apart. This is referred to as the member moment capacity of the section.

Designation and Notation

The designation and notation used for the hollow flange channels in this document are illustrated in the following example:

200 x 60 x 20 x 2.0 HFC

where 200 = section depth, d
60 = flange width, b_f
20 = flange depth, d_f
2.0 = web thickness, t



General Purpose Beam

For some applications, such as floor beams, the critical flange of the section is fully restrained and the **section** moment capacity governs for the beam bending strength. For various other applications such as rafters and purlins subject to uplift, the critical flange is not fully restrained, and the **member** moment capacity governs for bending strength. Therefore a general purpose beam must provide an efficient solution for both of these situations.

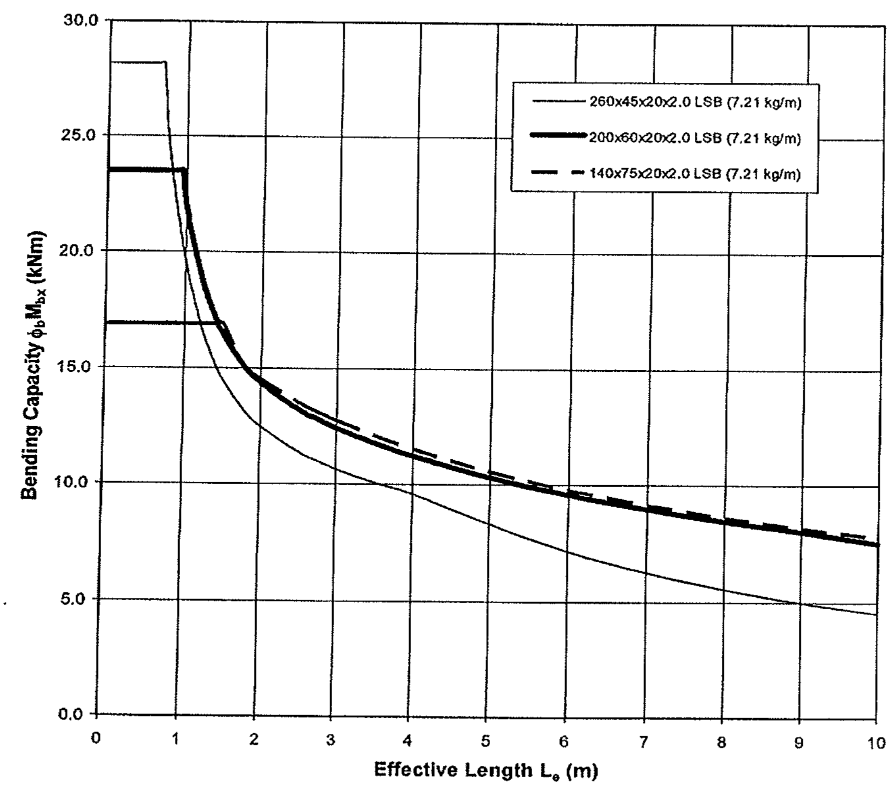
However, at the time of filing the present patent application, it was not obvious that a beam as defined in claim 1 of the present application, including the claimed dimensional ratios, would provide an efficient solution for both of the above situations. Yet as demonstrated by the data below, unexpected superior results for both of the above situations are exhibited by beams as defined in claim 1. All data contained in Figures 4 to 10 following are calculated in accordance with the Australian Standard AS/NZS 4600: 2005 Cold-Formed Steel Structures.

Referring to Figure 4, the effective length of a beam on the horizontal axis represents approximately the spacing of lateral restraints for the beam. The horizontal portion of the bending curves is the section moment capacity, and the remainder of the curves are the member moment capacities. Therefore the optimum general purpose beam must provide good performance (be efficient) over the full range of effective lengths, including section moment capacity and member moment capacity.

The 200 x 60 x 20 x 2.0 HFC represents one section size that fits the optimum geometric proportions represented in the present patent application. Compared to the other sections shown, it has a slightly better than average section moment capacity, and a relatively high member moment capacity compared to the others. All sections in the graph have the same mass, so the comparison of the section is also in terms of bending efficiency. All sections also have the same flange depth (d_f) and thickness (t).

If the hollow flange channel was to be optimized for section moment capacity when the beam is fully restrained, then a tall and narrow (slender) section would be the most efficient. The 260 x 45 x 20 x 2.0 HFC in Figure 4 is such a beam where the section depth (d) has been increased and the flange width (b_f) has been decreased. It can be clearly seen that, while the section moment capacity is higher, the member moment capacity is significantly lower. These slender sections would also suffer a reduction in shear and web crippling strength because of buckling of the more slender web.

If the section was to be optimized for member moment capacity with longer unrestrained lengths, then a shorter and wider (stockier) beam would be more efficient. The 140 x 75 x 20 x 2.0 HFC in Figure 4 illustrates this. The section moment capacity is much lower, but in this case the member moment capacity is only slightly higher than the section with optimum proportions.



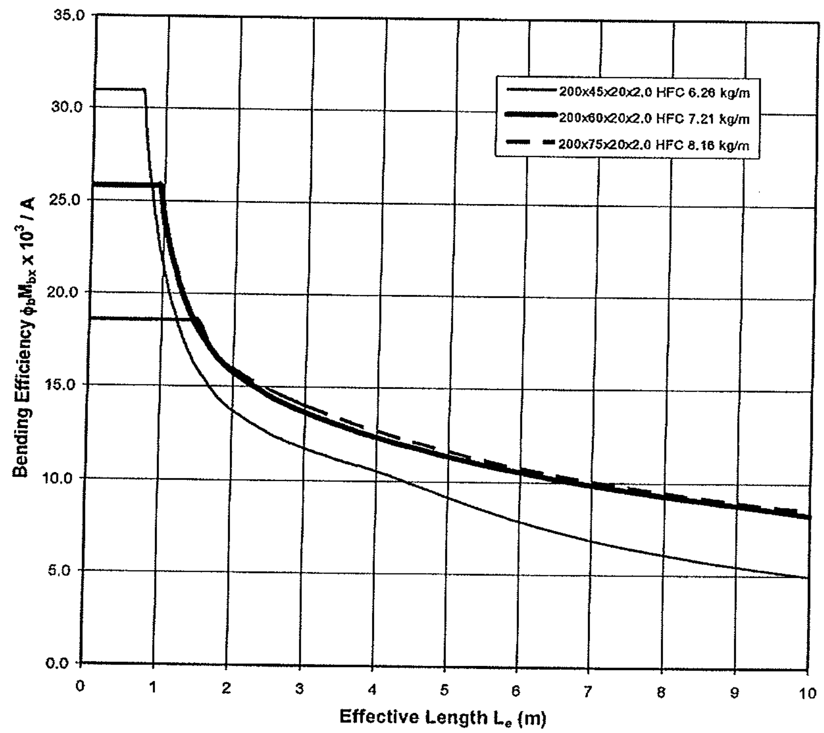
Section	b_f / d	b_f / d_f	b_f / t
260 x 45 x 20 x 2.0 HFC (7.21 kg/m)	0.173	2.25	22.5
200 x 60 x 20 x 2.0 HFC (7.21 kg/m)	0.3	3.0	30
140 x 75 x 20 x 2.0 HFC (7.21 kg/m)	0.536	3.75	37.5

Fig. 4 Bending Capacity Curves for Constant Flange Depth and Thickness

The distinctive buckling behaviour of the hollow flange sections has a large impact on the bending performance. It is influenced by a combination of web slenderness and the torsional rigidity of the flanges. The torsional rigidity of the flanges is determined by the flange width (b_f) and the flange depth (d_f). The web slenderness is determined by the section depth (d), the associated flange depth (d_f) and the section thickness. All geometric parameters in combination have an influence.

If we consider how to optimize the section without changing the section depth (d), we know from simple engineering mechanics that the maximum bending strength will be obtained by placing as much of the material as possible in the flanges furthest from the neutral axis. In the case of a hollow flange channel this would mean that there would be no gap between the outer and inner faces of the hollow flanges, which means that the flanges would no longer be hollow. There is also a minimum practical limit on the depth (d_f) of the hollow flange, which is about 4 times the thickness, to allow for suitable bend radii at the flange corners.

Figure 5 shows three sections with the same depth and thickness, but different flange width and depth combinations such that they all have the same mass. The section with the proportions to which the patent claims converge is the 200 x 60 x 20 x 2.0 HFC. It can be seen in this example as well that the 200 x 60 x 20 x 2.0 HFC section has an average section moment capacity and a better than average member moment capacity. However, the section with the wider but shallower flange has a higher section moment capacity, and a lower member moment capacity. The section with the narrower but deeper flange has a lower section moment capacity, and a higher member moment capacity. Again, as shown, the section with the geometric proportions in accordance with the patent claims offers the best solution for a general purpose beam.



Section	b_f / d	b_f / d_f	b_f / t
200 x 65 x 10 x 2.0 HFC (7.21 kg/m)	0.325	6.5	32.5
200 x 60 x 20 x 2.0 HFC (7.21 kg/m)	0.3	3.0	30
200 x 55 x 30 x 2.0 HFC (7.21 kg/m)	0.275	1.83	22.5

Fig. 5 Bending Capacity Curves for Constant Depth and Thickness

The clear conclusion from Figures 4 and 5 is that the section with geometric proportions in accordance with the claims of the present patent application offers a significantly superior solution for a beam that has to perform well over a full range of effective lengths – i.e., as a general purpose beam. However, the following discussion will also show how these geometric proportions are "special" in that they, in combination, provide an optimum solution (i.e., provide the most efficient use of material) for the section moment capacity of the section. There is no reason a design engineer skilled in the art at the time of filing of the present application would have been directed to this solution by the prior art. It is also reasonable to assume that these optimal proportions are specific to the hollow flange shape specified in the present patent application, and may be different for the flange shapes specified in the prior art, such as in the reference of Oliver et al cited by the Examiner.

Optimization for Section Moment Capacity (fully restrained beam)

The procedure for establishing the optimum proportions is outlined below.

Equation 3.3.2.2 of AS/NZS 4600: 2005 gives the nominal section moment capacity as:

$M_s = Z_e f_y$

where Z_e = effective section modulus calculated with the extreme compression or tension fibre at f_y.
f_y = yield stress used in design

The bending efficiency in the following graphs is represented by the expression (Z_e / A) where A is the cross-sectional area of the hollow flange channel. It is easier to use the section properties in this manner rather than calculate the bending capacity and divide by the section mass. The section moment capacity is directly proportional to the effective section modulus (Z_e), and the mass (which represents the cost) is directly proportional to the cross-sectional area of the section (A).

The ratios of the hollow flange channel dimensions given in the claims of the present patent application are summarised in Table 1.

Table 1 Summary of the Patent Application Claims for the Section Geometry

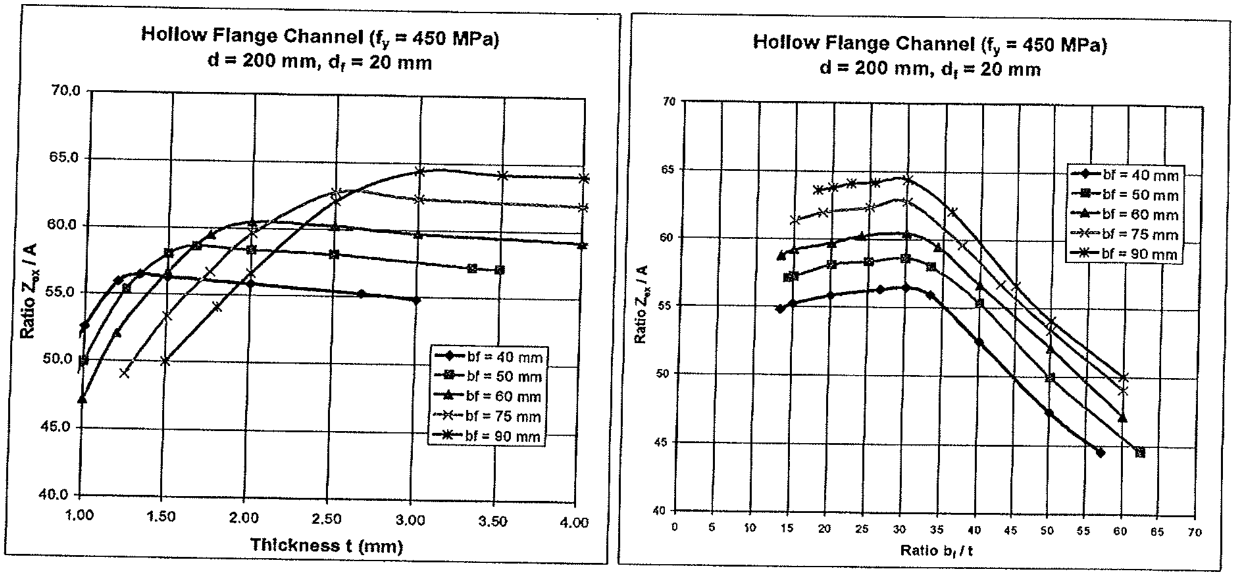
Claim No.	b_f / d	b_f / d_f	b_f / t
1	0.2 to 0.4	1.5 to 4.0	15 to 50
4	0.2 to 0.4	2.5 to 3.5	15 to 50
5	0.2 to 0.4	2.8 to 3.2	15 to 50
6	0.25 to 0.35	1.5 to 4.0	15 to 50
7	0.28 to 0.32	1.5 to 4.0	15 to 50
8	0.2 to 0.4	1.5 to 4.0	25 to 35
9	0.2 to 0.4	1.5 to 4.0	28 to 32

The three dimensional ratios are grouped together in claim 1 because they are all interrelated. This will become evident in the following analysis and discussion. One of the reasons for this interrelation is the fact that the flange width (b_f) appears in each of the three ratios.

The **flange width to the thickness ratio (b_f / t)** given in the claims converges on a ratio b_f / t = 30 (refer to Table 1).

Figure 6 gives an example of a beam with a constant depth d = 200 mm and flange depth d_f = 20 mm, and a range of different flange widths (b_f) and thickness (t). For each flange width there is a definite optimum thickness (t) and hence flange width to thickness ratio b_f / t = 30. Taking into account practical considerations, it is logical that selected beams

would have this ratio within a small range either side of this optimum. For each line in the graphs of Figure 6, the ratio of flange width to section depth (b_f / d) is constant.



(a) (b)

Fig. 6 Effect of Flange Width to Thickness Ratio (b_f / t)

When we consider the same sections with depth d = 200 mm, flange depth d_f = 20 mm with constant thickness, but vary the flange width, the results are as shown in the graphs in Figure 7. Figure 7(a) shows that for each thickness there is a different optimum flange width, while Figure 7(b) shows that the ratio of flange width to thickness is fairly constant at (b_f / t = 33.3). For each line in the graphs of Figure 7, the ratio of flange width to section depth (b_f / d) is varying.

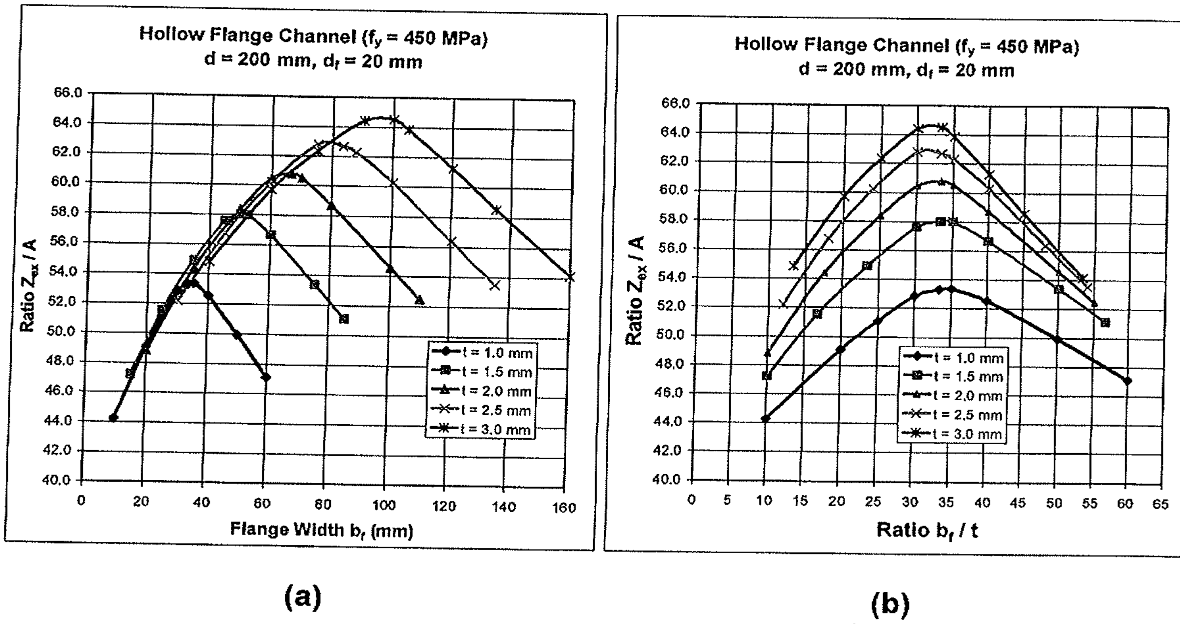


Fig. 7 Effect of Flange Width to Thickness Ratio (b_f / t)

The **flange width to the beam depth ratio (b_f / d)** given in the present patent application converges on a ratio $b_f / d = 0.3$ (refer to Table 1).

Figure 8 gives an example of a beam with the optimum flange width to thickness ratio $b_f / t = 30$ already established, and constant flange width to flange depth ratio $b_f / d_f = 3.0$. Four section depths are plotted wherein the flange width (b_f) is varied. It can be seen from the graph that there is an optimum value of the ratio $b_f / d = 0.33$ for each section depth.

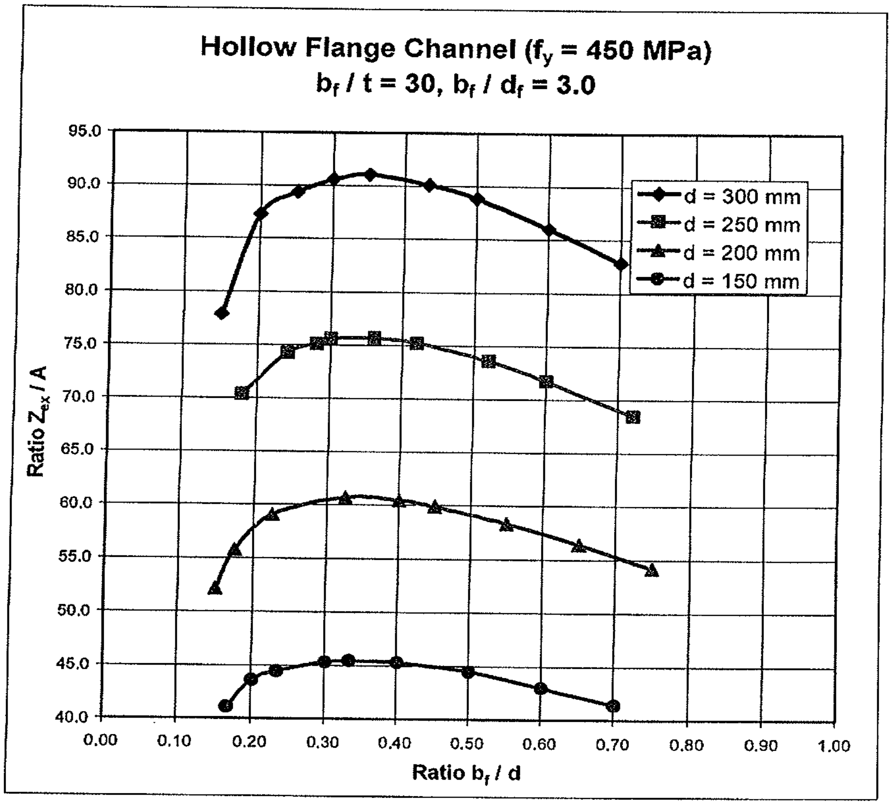
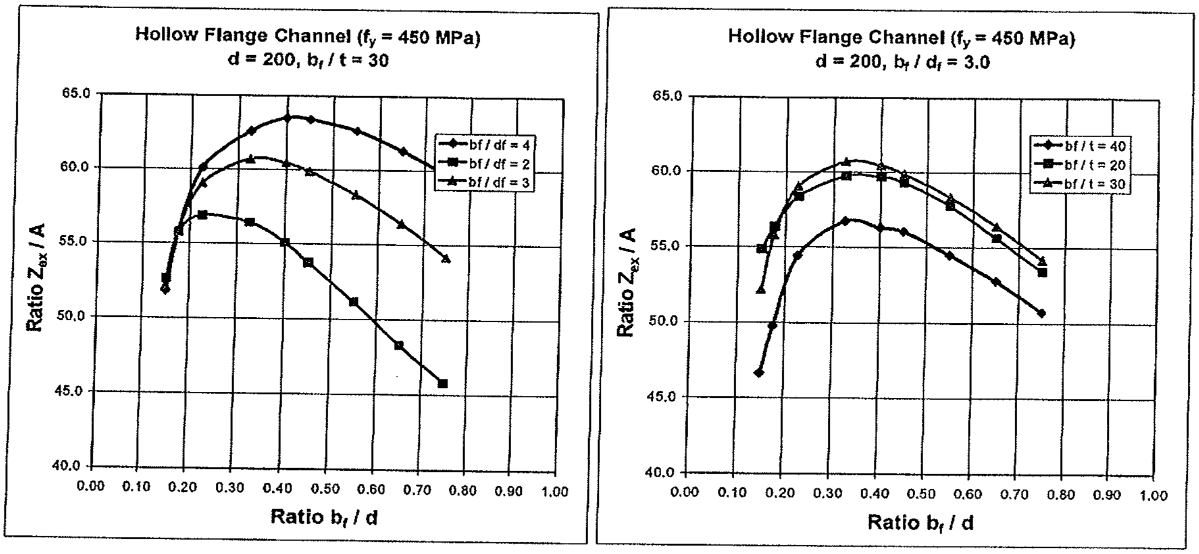


Fig. 8 Effect of Flange Width to Beam Depth Ratio (b_f / d)

The **flange width to the flange depth ratio (b_f / d_f)** given in the present patent application converges on a ratio b_f / d = 3.0 (refer to Table 1).

It has already been established that there is an optimum flange width to thickness ratio (b_f / t = 30) and an optimum flange width to section depth ratio (b_f / d = 0.3). It has also been noted that all of the three ratios included in the present patent application are interrelated. This has partially been illustrated in the graphs already presented. Figure 9 shows the relationship between the b_f / d_f ratio and the ratios b_f / d and b_f / t.



(a) (b)

Fig. 9 Effect of Flange Width to Beam Depth Ratio (b_f / d)

Figure 9(a) gives an example of a beam with a constant depth d = 200 mm and the optimum flange width to thickness ratio $b_f / t = 30$, and a range of three different flange widths to flange depth ratios (b_f / d_f). It can be seen that the optimum flange width to section depth ratio (b_f / d) is different for each flange width to flange depth ratio (b_f / d_f). However, we have already established that the optimum flange width to section depth ratio is $b_f / d = 0.33$ which corresponds to the ratio $b_f / d_f = 3.0$. Figure 9(b) further shows that when $b_f / d_f = 3.0$, the ratio of $b_f / d = 0.33$ is optimum for all ratios b_f / t, but the previously established optimum $b_f / t = 30.0$ gives the best efficiency.

Member Capacity (unrestrained beam)

There are no optimal geometric ratios for the member moment capacity of the hollow flange channel. However, the sections with the optimum proportions for section moment capacity perform much better than average for longer effective lengths as shown previously in Figures 4 and 5. Therefore the proportions presented in the present patent application provide the best option for a general purpose beam.

Comparison with the Cited Prior Art

Oliver et al. (UK Patent Application Publication 2261248 A) present a hollow flange section, similar but not the same as, the present invention of Bartlett et al. Although Oliver et al. state that their invention can be used as a structural member subject to bending stress in at least one direction, the primary purpose is clearly for use as a ladder stile. A ladder stile is quite small, and is very specific in the way it is loaded and restrained, being different to general purpose structural beams. Oliver et al. offer no guidance whatsoever in regard to optimising the section shape for ladder stiles or any other application.

The present patent application by Bartlett et al. presents a hollow flange channel wherein the geometric proportions provide significant, unexpected, and superior qualities for use as a general purpose beam, as has been shown above. The data are based on extensive numerical investigation, testing, and experience, and apply to any physical size of hollow flange channel having a shape defined in Claim 1 of the present patent application. These geometric proportions would not have been obvious to an ordinary person skilled in the art at the time of filing of the present application, because hollow flange channels having a shape as defined in the present claim 1 had not previously been considered for application as general purpose beams. The absence of any technical literature, standards or performance data concerning this type of section prior to the filing of the present patent application attests to this. Engineers generally think of I-shaped sections for general purpose beams. If an engineer was considering developing a cold-formed section for a general purpose beam, then history suggests that he or she would be more likely to adopt a "C" or "Z" shaped section.

Figure 10 shows a bending capacity comparison between a hollow flange channel with the optimum geometrical proportions of the presently claimed invention and a commercially available cold-formed C section of the same mass. The hollow flange channel has a slightly better section moment capacity (approximately 0 – 1.0 m effective lengths) and a slightly reduced bending capacity to about 3.0 m effective length due to the effect of the lateral distortional buckling. Beyond that the hollow flange channel has a much larger member moment capacity, even up to more than 3 times that of the C section at 10.0 m effective length. These benefits would not be achieved with other than the optimum geometric proportions of the hollow flange channel as defined in the claims of the present patent application. (Note: the bending capacity of the Cee section is also calculated in accordance with AS/NZS 4600: 2005. This standard is technically identical to the AISI-NAS except that the AISI-NAS does not have design rules for hollow flange channels.)

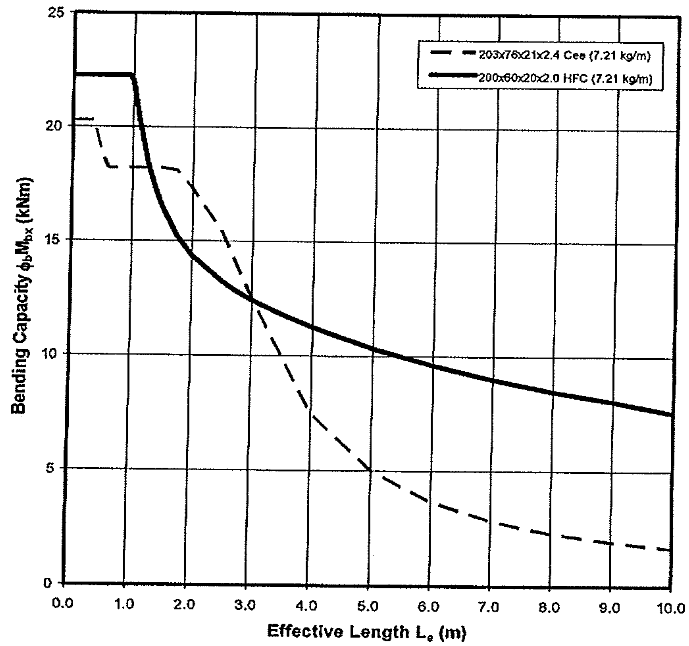
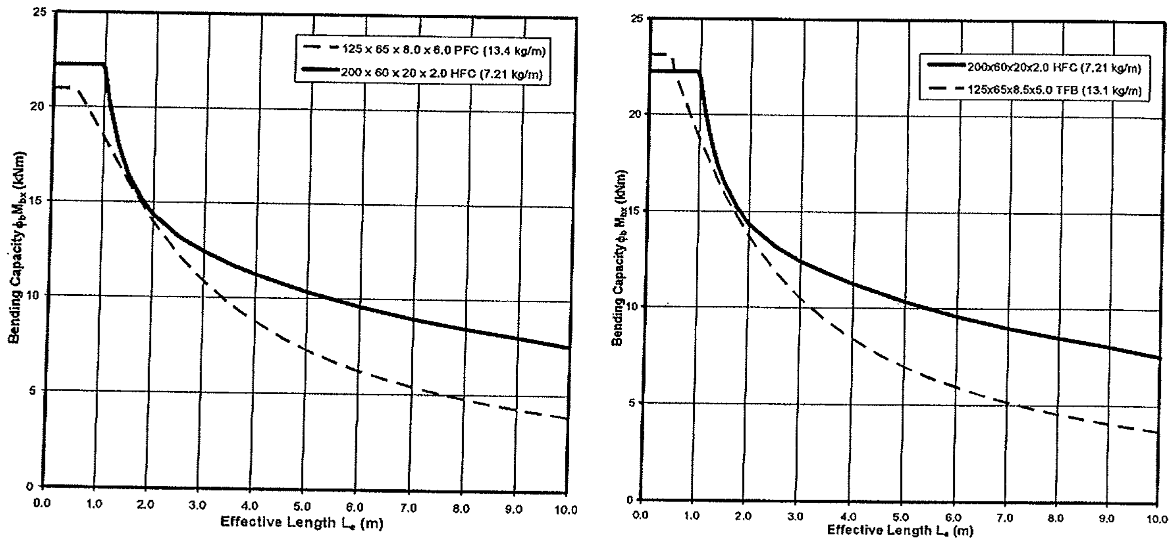


Fig. 10 Comparative Bending Performance of a Hollow Flange Channel and a C Section

Figure 11(a) and (b) show comparisons between a hollow flange channel with the optimum geometric proportions of the presently claimed invention and a hot rolled I-beam (TFB) and a parallel flange channel (PFC). In both cases the section moment capacity is similar, but the member moment capacity of the hollow flange channel becomes significantly greater than that of the other sections as the effective length increases. It should also be noted that the mass of the hollow flange channel is only about 55% that of the hot rolled sections. Again, these benefits would not be achieved with other than the optimum geometric proportions of the hollow flange channel described by claim 1 of the present patent application. (Note: the bending capacities of the TFB and PFC are calculated in accordance with AS 4100: 1998 Steel Structures. This standard is very much the same as the AISC Specification.)



(a) **(b)**

Fig. 11 Comparative Bending Performance of a Hollow Flange Channel with a Tapered Flange Beam (TFB) and a Parallel Flange Channel (PFC)

Conclusion

In conclusion, I believe that a beam as defined by the present claim 1, including the claimed dimensional ratios, does exhibit significant, unexpected beneficial results as illustrated herein and such a beam would not have been obvious to a person skilled in the art at the time of filing of the present application.

References

Standards Australia / Standards New Zealand, (1996), Cold-Formed Steel Structures, AS/NZS 4600, Sydney, Australia.

Standards Australia / Standards New Zealand, (2005), Cold-Formed Steel Structures, AS/NZS 4600, Sydney, Australia.

Standards Australia, (1998), Steel Structures, AS 4100, Sydney, Australia.

Hancock, G.J., (2007), "Design of Cold-formed Steel Structures (to AS/NZS 4600: 2005)", 4th edition, Australian Steel Institute, Australia.

Mahaarachchi, D. and Mahendran, M. (2005), "Lateral Buckling Tests of LiteSteel Beam Sections", Research Report No. 1, Queensland University of Technology, Brisbane, Australia.

Mahaarachchi, D. and Mahendran, M. (2005), "Section Capacity Tests of LiteSteel Beam Sections", Research Report No. 2, Queensland University of Technology, Brisbane, Australia.

Mahaarachchi, D. and Mahendran, M. (2005), "Finite Element Analysis of LiteSteel Beam Sections", Research Report No. 3, Queensland University of Technology, Brisbane, Australia.

Mahaarachchi, D. and Mahendran, M. (2005), "Moment Capacity and Design of LiteSteel Beam Sections", Research Report No. 4, Queensland University of Technology, Brisbane, Australia.

Mahaarachchi, D. and Mahendran, M. (2006), "Material Properties, Residual Stresses and Geometric Imperfections of LiteSteel Beam Sections", Research Report No. 5, Queensland University of Technology, Brisbane, Australia, July.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issued thereon.

Respectfully submitted,

R. T. Dempsey

16/12/08

Date